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THE HEART AND ITS FUNCTION.

CHAPTER I.

WHY WE HAVE A HEART.

NOTWITHSTANDING the many millions of years which our world and race have, according to some, already existed, the discovery of the circulation of the blood is but a thing of yesterday. From some passages in his work, "De Trinitatis Erroribus," published in 1531, Servetus would seem to have been fully aware of the lesser or pulmonary circulation. But it was not till 1628 that the doctrine of the circulation of the blood through the system generally was actually published by Dr. William Harvey, though indeed he had taught it publicly from the year 1619. It was not, however, till 1661, more than thirty years subsequently, that the circulation of the blood was actually demonstrated by means of the microscope, by Malpighi, so that this important fact has been known for little more than two centuries.

The whole quantity of blood in the body has been reckoned at about one-fourteenth part of the weight of the body; the blood in the body of a man weighing fourteen stone will therefore amount to one stone, or fourteen pounds. If we accept this as a probable average of the weight of blood in the body, then as fourteen pounds amount to 224 ounces, and as the left ventricle contains, as we suppose, only 3 ounces, it follows that the whole blood of a man weighing 196 lbs. passes through his left ventricle in nearly 75 (74·6) of its systoles or contractions. And as we suppose the heart to contract only 70 times in a minute, then the whole of the blood of such a man passes through his heart 48 times in one hour, or 1152 times in one day. Of course the length of time that the whole of the blood in a man takes to pass through his heart depends upon three factors,—first, the actual amount of blood he possesses; second, the size of his ventricular cavity; and thirdly, the rate of its pulsation.

The actual velocity of the circulation, the time that one blood globule takes to circulate, that is, to return to the heart after leaving it, is a somewhat different matter, and has been found by Vierordt to be nearly equal to the same number (27) of ventricular systoles in all animals. Of course the time actually involved in these twenty-seven pulsations varies with the rate at which the heart

beats; but in man, if we suppose his heart to beat at the rate of 70 pulsations per minute, it will be a trifle over twenty-three seconds. In man, therefore, one globule courses round the body in twenty-three seconds, and the whole mass of blood completes its circulation in seventy-five seconds.

The use of the blood is to supply nourishment to every part of the body, and to remove all those waste matters which result from every act evincing life; and the object of the circulation of the blood is to bring that fluid into contact with every part, so that these ends may be thoroughly carried out. The blood is derived from the food, and consists of a watery solution of the constituents of the body, in which are suspended a number of globules. The greater number of these are red (Fig. 1), and give the blood its crimson colour; the others (Fig. 2) are

FIG. 1.



FIG. 2.



white or colourless. These white globules never in health present a higher proportion to the red than 1 to 300 or 400; but the proportion is often much less, and

they mostly end in becoming red ones. The use of the red globules is to carry oxygen to every part, and so to supply what is needful for those chemical changes which precede every manifestation of life. Because every act by which we exhibit life is accompanied by the conversion of potential into kinetic energy, and this conversion of one form of energy into the other is mainly due to the oxidation of the organic constituents of the body.

Energy is simply a term used to express the power of doing work. *Potential* energy is the latent power of doing work; and is possessed, in relation to gravity, by a stone resting on the brow of a hill; in relation to chemistry, by a mass, say, of gunpowder. If we give the stone a push, so that it rolls down hill, or if we blow up the gunpowder by applying a lighted match to it, we in each case convert the latent or potential into *kinetic* energy. We all of us know that we possess a certain amount of potential energy—power of doing work, which we transmute into labour of some kind, digging, hammering, or walking, &c. But few of us realise that thought itself is a product of the transformation of energy, and that in merely living, without doing what we regard as any actual work, the same transformation of potential into kinetic energy is continually taking place in every part of our body. The products of the chemical changes upon which this depends are thrown out of the body as waste,

and have to be replaced with fresh oxidisable material. Every living creature must therefore have a circulation of blood, or nutritive fluid, throughout its body; and though the manner in which this circulation is carried out is not the same in all animals, it is based on the same plan, various parts being added as the animal rises in the scale of being, and becomes itself more complex in structure. The simplest kind of circulation is found in the lowest forms of animal life, such as the sea anemones; in them the blood, or fluid elaborated in the stomach, simply permeates from cell to cell; by-and-by a system of canals, or blood-vessels, is added; and though at first, as in worms, leeches, &c., these vessels serve by their own contractions to propel the blood through the body, yet ere long we find the contractions of the vessels supplemented by the addition of one or more contractile sacs, the earliest development of these being found in crabs, lobsters, and animals of that class. This pulsating sac is the first rude development of a heart, an organ which becomes of greater importance as we rise in the scale of being, until in the highest classes of animals it assumes a paramount place as the great centre of the circulation.

CHAPTER II.

THE STRUCTURE OF THE HUMAN HEART.

THE simple pulsatory sac, which is the earliest form of heart found in animal life, is equivalent to that part of the human heart termed the *ventricle*, because it bellies out as it fills with blood, as an india-rubber syringe does when it fills with water. The use of this pulsating sac is to assist in propelling the blood, and it acts very much like an ordinary india-rubber Higginson's syringe; the part which we compress with the hand is the heart—self-acting of course, and provided with similar appliances in the shape of valves to prevent regurgitation and guide the fluid in its onward course. The *fish heart* is slightly in advance of this simple form; it is still a single heart, but it consists of two cavities, one of which has thinner walls than the other, and is termed the *auricle*, because the similar portion of the human heart resembles a dog's ear. The auricle acts as a mere reservoir for the ventricle; during the contraction of the ventricle, and for a little longer, it receives the blood coming to the heart from the general system; it then contracts and forces the blood into the ventricle, which distributes it throughout the whole body, valves again preventing its regurgitation into the auricle. Fig. 3 is a representation of a heart

of this sort. *a* is the auricle, and *b* the ventricle. Fig. 4 is a diagram of the circulation carried on by such a heart. *a* is the auricle and *b* the ventricle, sending the blood first of all through the arteries of the gills, or respiratory organs. *e e* where it is thoroughly aërated, and then

FIG. 3.



FIG. 4.

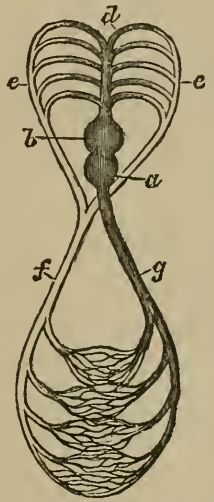
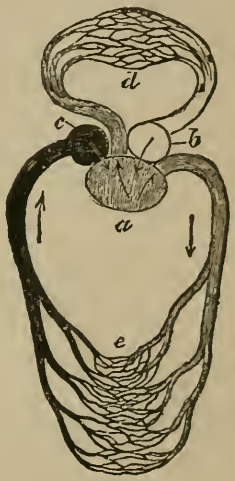


FIG. 5.

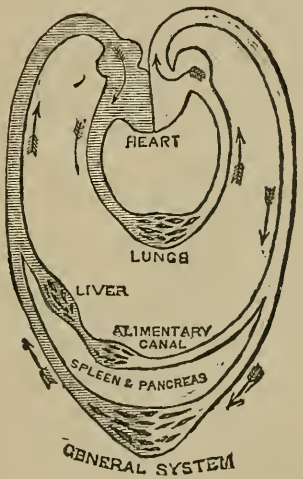


passed on to the general system through the great artery *f*, being returned to the auricle through the great systemic vein *g*. In the *reptiles* we have a heart very much of the same type as in the fish, but provided with two auricles, one of which, *b* Fig. 5, receives the blood from the lungs,

as the respiratory organs are termed when contained within the chest; while the other, *c*, receives that from the general system. The blood from the lungs is thoroughly aërated, bright scarlet, and, as we say, *arterial* in its character; that from the general system is of a dark purple hue, *venous* as we call it. Both kinds of blood are poured into the one ventricle *a*, which sends the mixed blood to the lungs *d* on the one hand, and to the general system *e* on the other. (In the diagram the dark shading represents the course of the venous blood, the light that of the arterial, and the intermediate that of the mixed blood.) In all these animals the blood is cold, but when we rise to the higher types—the birds and mammals—we find the blood warm, and the whole organism possessing a greater energy of vitality, largely due to the circulation through it of a more highly oxygenated blood, as we see represented in Fig. 6. Here we see one half entirely light and the other wholly dark, there is no admixture anywhere; the very heart is doubled, so that there may be no chance of any mixture, and we have a venous heart—auricle and ventricle—and an arterial heart having a similar structure, the lungs, or aërating organs, lying between them. Both hearts are combined into one organ, commonly called *the heart*, the two halves of which act together equally and simultaneously, except under certain unusual morbid condi-

tions, when sometimes the one half and sometimes the other may be found to predominate alternately. Before birth the unborn mammal breathes no air, and the structure of the heart and blood-vessels is somewhat modified, so that the circulation under these circum-

FIG. 6.



stances is reptilian in its character. But immediately after birth these modifications disappear, and the circulation through the two hearts becomes distinct and separate, venous on the one side—that is, consisting only of dark purple blood; and arterial—that is, having only

bright scarlet and freshly oxygenated blood—on the other. It now and then happens that the modifications in the organs of circulation which exist in all before birth, remain permanent after it; but these exceptional infants have a low vitality, with lips and extremities livid and cold, and they seldom live long.

The HUMAN HEART follows the general type common to all mammals, and every part of the following description may be quite easily followed by a reference to the heart of an ox or sheep. The heart has been roughly estimated as about equal in size to the closed fist of the person to whom it belongs; it has, like an egg, a broad end, termed its *base*, which is directed upwards, backwards, and to the right; and a pointed end, which is called its *apex*, and is directed downwards, forwards, and to the left, so as to lie opposite the interval between the fifth and sixth ribs, about two and a half inches from the middle of the breast bone. The apex is that part of the heart which is distinctly felt to strike the chest wall when we lay our hand over the left side of the chest.

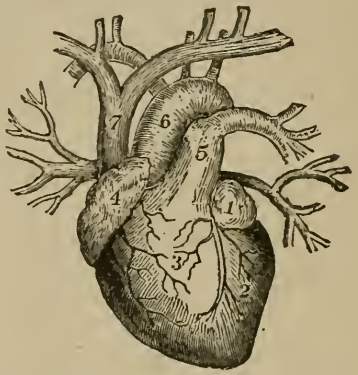
The heart lies within the cavity of the chest, between the two lungs, but much more on the left side than the right one. It partly rests upon the diaphragm or midriff, that is, the arched muscular partition which stretches across the body, and divides the cavity of the chest from that of the belly, and is partly suspended by the large

vessels connected with it. It is enclosed within a sac termed the *pericardium,* not as an apple is when actually within a bag, but as if an apple were closely enfolded by a closed bag being wrapped round it. In this way one side of the thin pericardial sac closely enfolds the heart, and is adherent to it, creeping a short way up the roots of the large vessels, and from these it is reflected to form the other or outer side of the bag. Actually within the bag itself there is only a little steamy moisture, which sometimes before death, and always after it, is found condensed as a yellowish serum or watery fluid ; hence the pericardium is called a *serous sac* or bag. It is easy to see that with a bag so constructed surrounding it, the heart, though not actually within the sac, has yet quite as much freedom of movement as if it were, while it has the additional advantage of having its own surface carefully protected and lubricated. Around the serous sac there is a firm fibrous outer coating, which is attached below to the central tendon of the diaphragm, and is continuous above with the fibrous sheath of the great vessels ; it therefore helps to support and to keep the heart in its place.

Within the pericardium the heart lies very much as it is represented in Fig. 7 ; the right or pulmonary heart being in front and a little to the right of the left or systemic heart. The heart measures about five

inches in length by three and a half in breadth, and weighs upon an average about ten ounces, the heart of a man weighing about one ounce more than this, that of a woman about one ounce less. (John Reid.) The

FIG. 7.

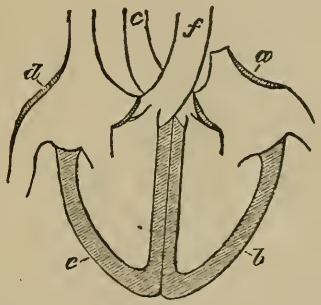


In this figure the numeral 1 is placed on the appendix or loose portion of left auricle, the body of which lies behind the heart, between the two lungs, 2 on the left ventricle, 3 on the right ventricle, 4 on the right auricle, 5 on the pulmonary artery, 6 on the aorta, or large artery which conveys from the heart all the blood going to the body, and 7 on the vena cava superior, which, with another vein not seen, called the inferior cava, convey all the blood from the body to the heart, while at each side the pulmonary veins are seen passing from the lungs to the body of the left auricle which lies at the back of the heart between the two lungs.

heart, as already stated, is a double organ, and in Fig. 8 the two halves of this organ are diagramatically represented in section as placed side by side, so as to

exhibit the relation to each other of the four cavities comprised in these two halves. Two of these cavities, *a* and *d*, have, as we see, much thinner walls than the other two, *b* and *e*. The two thin-walled cavities are termed *auricles* because there is attached to the body of each of them an appendix supposed to resemble a dog's ear (*auricula*). The thick-walled cavities are termed *ventricles* because when full they swell out and are *bellied*.

FIG. 8.



These four cavities are of nearly equal capacity, the two ventricles containing nearly three fluid ounces each, while the auricles scarcely contain so much. The two sets of cavities are completely separated from each other by a fixed and solid partition extending from the base to the apex of the heart, which prevents all direct communication between them. On the other hand, the two cavities on each side of this solid septum or dividing wall, do

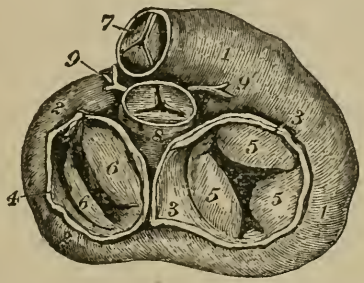
communicate with each other, being only separated transversely by a movable partition, consisting of membranous valves which open when the auricles contract to permit the onward flow of the blood, and close when the ventricles act to prevent the blood flowing back into the auricles. On the left side the valve consists of two segments, and is called the bicuspid or mitral valve; while on the right side there are three segments, and the valve is called the tricuspid. The cavity above these valves on either side is the auricle; the cavity below them, the ventricle.

A reference to the diagram will also show that each ventricle is provided not only with an inlet, as just described, but also with an outlet, as at *c* and *f*. Upon each ventricular outlet there is attached an elastic tube, these being respectively the two great arteries (arterial trunks) of the body; *c*, the aorta passing off from the left ventricle, and conveying from it the blood which is to be distributed throughout the body for its nourishment; and *f*, the pulmonary artery coming off from the right ventricle, and carrying to the lungs the blood collected from every part of the body by the veins, to be aerated, that is, to receive there a fresh supply of oxygen, without which, as we have already learned, every manifestation of life would cease. At the outlet of each ventricle a valvular apparatus is placed, consisting, each of them,

of three pouch-like valves, called the aortic and the pulmonary semilunar valves. The segments of each of these valves open outwards to permit the blood to flow out, but close when the emptied ventricle recommences to dilate in order to prevent any flow of the blood backwards (regurgitation).

Fig. 9 represents the base of the ventricular cone,

FIG. 9.



The segments of the tricuspid valve, which close the opening in the right ventricle leading into the right auricle, are marked by the numeral 5. 1 is placed on the base of the right ventricle, which terminates in what is termed the *conus arteriosus*, leading into the pulmonary artery; the numeral 7 is placed on the semilunar valves closing this opening. The base of the left ventricle is marked by the numeral 2; the segments of the mitral valve by 6; those of the aortic semilunar valves are seen above 8, which is placed on the base of the aorta; 9 points out the left, and 9′ the right coronary artery, which supply the heart itself with blood; while 3 and 4 point out the remains of the right and left auricles respectively.

with the four openings just described, and the valves which guard them and so far direct the blood-current in

its onward course by preventing its flowing in any other direction.

A firm fibrous or tendinous ring surrounds the four openings described, and to it the valves are attached, as well as the muscular fibres of the auricles superiorly, and inferiorly those of the ventricles, which are only indirectly connected with each other by means of this fibrous ring. The muscular fibres of the heart resemble those of the voluntary muscles in being of a deep red colour and marked with transverse lines (when examined microscopically); but they differ from those of the voluntary muscles in that these lines (*striæ*) are less distinctly marked, that the fibres frequently interlace, that they are more closely packed together, and have but little intervening (loose cellular) connective tissue, that they are not under the influence of the will, and also in several other less important but not less distinctive peculiarities.

The heart is almost entirely made up of muscular fibres, which are arranged after a fashion that seems sufficiently complex to the uninitiated, and indeed it is only recently that Dr. Pettigrew has succeeded in so unravelling them as to show the extreme simplicity of arrangement that underlies this seeming complexity, and its singular adaptation to the end in view—the complete emptying of the heart in such a fashion that the termination of its contraction initiates the succeeding dilatation.

The interior of the heart is lined by a delicate membrane called the *endocardium;* and the movable partitions, which act as valves at the four openings into the ventricles, are formed by duplications of this lining membrane, strengthened by tendinous expansions of the fibrous rings already mentioned. The semilunar valves, at the mouths of the aorta and pulmonary artery, are each composed of three segments which flap back against the arterial walls to permit the escape of the blood into the artery; but whenever this is ended, and the blood threatens to return into the ventricle, now beginning to dilate, the three segments of the valve fall together in the same plane, and completely prevent any backward flow. The valves between the auricles and ventricles open into the ventricles to permit the blood to flow from the one to the other, their edges have therefore to be secured to prevent them being flapped back into the auricles at the moment that the ventricle contracts. This is managed by means of tendinous cords attached to the free edges and under surfaces of these valves, the other ends of these cords being attached to fleshy projections on the inside of each ventricle, called the *columnæ carneæ*, or fleshy columns, which are part of the general heart muscle detailed for this special duty. When the blood flows into the ventricle the segments of the valves are floated up, and when they reach a certain height the tendinous cords come into action, and bring

the edges of these segments to bear on one another, back to back as it were, so that during the contraction of the ventricle not a drop can escape backwards into the auricles. Figures 10 and 11 represent the right side of the heart in the two opposite conditions referred to; in Fig. 10 the action of tendinous cords and fleshy columns in closing the valve is well seen. The mode of action of

FIG. 10.

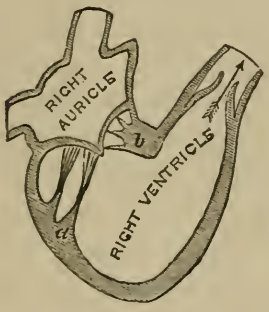
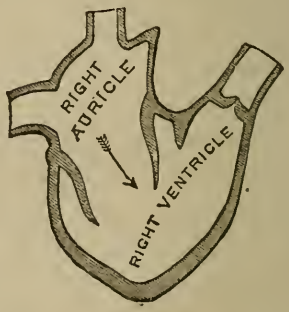


FIG. 11.



these valves may be also readily seen in a sheep's heart which has had the auricles cut away, the aorta and pulmonary artery tied, and water then poured into the ventricles so as nearly to fill them, a slight compression of the ventricles will then at once throw these valves into action. We can also put the aortic or pulmonary valves into action by pouring water into these arteries from above, when the water is seen not to escape, and the

closed segments may be readily enough distinguished through the clear water, or they may be looked at from below if we first cut off the ventricle, when they will be seen bulging downwards with their edges closely wedged together so as to permit not a drop to escape.

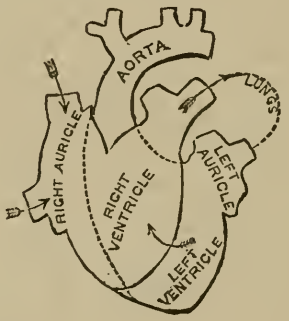
Such, then, is a concise account of the structure of the heart itself; but it would be of no use unless provided with channels through which it could exert its function of sending the blood destined to irrigate and feed the tissues which make up the body. To this end we have connected with the heart a system of vessels through which the blood is conveyed, part of them distributing it throughout the body generally, and part carrying it to the lungs for the purpose of having it aërated.

The *aorta* (6 Fig. 7, p. 16) springs from the left ventricle and distributes the scarlet arterial or oxygenated blood throughout the body. The blood returns to the right auricle through the veins of a dark purple, or, as it is called, venous hue, a colour due to its having lost most of its oxygen, which has been replaced by carbonic acid; and the *pulmonary artery* (5 Fig. 7, p. 16) arises from the right ventricle and carries this venous blood to the lungs, where it loses its carbonic acid and becomes oxygenated afresh; from the lungs it is carried to the left auricle by the pulmonary veins, which are the only veins in the body that carry arterial, or bright-red blood, and

thence it passes anew through the frame; a glance at the diagram (Fig. 12) will make this plain.

Besides those very necessary and important vascular links which connect the heart with the rest of the body, and thus enable it to discharge its functions, there are

FIG. 12.



other links also which, though physically of but small account, are yet of vast physiological importance. There are the nervous cords and ganglia which regulate the movements of the heart, and connect it functionally with the rest of the frame.

CHAPTER III.

THE FUNCTION OF THE HEART, AND HOW IT IS PERFORMED.

THE function of the heart, the work which it has got to do, is to keep the blood moving through the vessels at such a rate, and at such a pressure, as will suffice for the maintenance of all the organic functions in their normal state.

This it does by alternate movements of expansion and contraction—pulsations, as these acts are termed—by which the blood is first received into the dilated cavities, and then forcibly expelled from them in the proper directions.

The cause of these movements has been an object of the deepest interest to medical philosophers in all ages; even in our own day it is one of the most difficult problems in physiology, and one to which any answer we can give can scarcely be called satisfactory.

The heart of a shark has been known to beat for hours upon the taffrail of a ship, and that of a frog will beat for twelve hours upon a plate.

Muscular movement is always originated by some stimulus, mechanical, chemical, or vital; there is no difficulty in understanding that in the ordinary conditions

of vitality the blood is that stimulant, the presence of which within the cardiac cavities stimulates their walls to contraction. But the heart, as we have seen, continues to beat when entirely empty of blood; nay, it has even been known to beat under the exhausted receiver of an air-pump. Its movements must therefore be either truly automatic, and consequently quite peculiar, or they are capable of being excited by stimuli so feeble in their character that no other muscle would respond to them. That is about all that we know, and, unsatisfactory as it is, we have no better explanation to offer. It is quite a different matter, however, to calculate the amount of work which the heart has to do; this can be very easily done from the datum of the blood pressure in the aorta which keeps the semilunar valves closed. This blood pressure must be overcome before the left ventricle can throw its contents into the artery, and by adding to this the similar work of the right ventricle it has been found that during each twenty-four hours the healthy average human heart does an amount of work equivalent to raising 92·425 tons one foot high, or of raising one ton over 92 feet high, for the terms are convertible. We may form some conception of the enormous energy of the human heart when we reflect that a good climber can only ascend 9,000 feet in nine hours, that is, can only raise his own weight 1,000 feet in one hour, that is, of

course, continuously for any length of time, while the work done by the heart is equivalent to raising its own weight (10 oz.) 13,860 feet high; and we may put this even more strikingly by pointing out that the most powerful engine ever made by man, the "Bavaria" locomotive of the Vienna and Trieste railway, can only raise itself through 2,700 feet in one hour; that is, its energy is less than one-fifth of that of the human heart (Haughton). Of course the actual amount of work done, both by engine and climber, is much greater than that done by the heart; but relative to weight, the energy of the heart far exceeds that of the other two.

Of itself this energy is quite sufficient to carry on the circulation, as we can see in certain cases of disease, where not only are the finger-nails seen to flush and pale alternately with each beat of the heart, but even the veins of the arm may be seen to pulsate centripetally, the blood-wave flowing onward toward the heart.

But, so rapid a passage, were it constant, would largely defeat the object of the circulation. We have seen that this is to maintain throughout the body a condition fit for the display of vital phenomena, by means of the nutritive material and chemical agencies supplied by the blood. That the frame may be benefited by these life-giving properties, the blood must not merely pass rapidly through the vessels, but must slowly permeate all the tissues; the

mere circulation through the blood-vessels, so obvious to all our senses, must be supplemented by a less obvious permeation of the tissues by the nutritive fluid, analogous to the cellular circulation of the lower classes of animals. While, to secure permanent uniformity of action, the blood supply must be continuous and not intermittent, and must be kept flowing onward at as uniform a pressure as possible. In the healthy state, this constancy of the rate and pressure of the blood-stream is secured by the elasticity of the arteries, which converts the intermittent cardiac blood-wave, recognised in the arteries as the pulse, into that equable and continuous stream which alone passes through the capillaries, or smallest vessels in the body, lying between the arteries and veins, the name being derived from *capillus*, a hair; for in health the propulsive action of the heart is indistinguishable beyond the arterioles, or smallest arteries. It is, however, none the less real, though unperceived. Fortunately for us it is not the sole agent concerned in maintaining the circulation of the blood, otherwise we would be in a much sorrier plight than we are, when our hearts get enfeebled or diseased. Were the arteries rigid tubes, like leaden water-pipes, exactly the same amount would flow out at the one end as was forced in at the other, and with the same intermittent action; the pressure inside the tubes might indeed vary, but would only show itself by the

force with which the fluid was ejected, and the occurrence of many of those vital phenomena with which we are all familiar would be prevented. We would either be wholly incapable of blushing or we would be always in a flame, our eyes would either always be dry or our tears for ever flowing. From this impassive condition we have been saved by the stop-cock action of the smallest arteries, which is the real source of the conversion of the intermittent action of the heart into a continuous flow. The elasticity of the arteries acts like the second ball in a hand-ball bellows, which renders continuous the intermittent action of our hand upon the terminal ball; but we all know how difficult it is to bring this action into play unless we first compress the tube leading off from the second ball; so, too, the elasticity of the arteries may be entirely nullified by paralysed or relaxed arterioles.

The supplementary or subsidiary forces which aid in maintaining the circulation of the blood may be divided into *extrinsic* and *intrinsic*. Under the *extrinsic forces* are comprised all those mechanical and chemical forces which suffice for the maintenance of the circulation in plants and in the lowest forms of animal life, such as *diffusion* or *osmosis* and *capillarity*, and to these we may also add *intermittent muscular action* and *thoracic aspiration*, the latter being a measurable force of very considerable importance. The *intrinsic forces* are of two kinds; first,

rhythmical vascular movement, which is most markedly automatic in the veins, though it is more easily seen in the arteries, where it is apt to be regarded as solely due to the propulsion of the blood-wave through them by the heart; and second, *cardiac aspiration*, some degree of which necessarily results from the untwisting of the cardiac muscle itself during its diastolic relaxation. It seems more philosophic to regard these intrinsic forces as entirely one in character, and perfectly analogous to the rhythmical pulsations of the dorsal vessel of insects, the pulsatory wave passing round the vascular system with the blood-wave, its two phases of diastole and systole —aspiration and propulsion—being everywhere distinguishable, though more markedly so in the heart, which is a diverticulum specially developed for certain specific purposes.

By-and-by we shall be more able to recognise the importance of knowing the great amount of work which the heart has to do, as also the fact that it is only one of a group of organs which make up what we call our body, all equally dependent on one another. The stomach cannot digest, unless the heart is able to keep the blood pressure up to such a pitch that the gastric juice is secreted normally both as to quantity and quality; but neither can the heart beat with sufficient force unless it is supplied with blood (digested food) fit to maintain its

power. There are but two organs out of this interdependent group of many, yet the most ignorant can readily recognise—even in this limited field—the difficulty as well as the importance of knowing where to begin in attempting to restore the balance of life. This is what the physician has to do, not in regard to two organs merely, but in regard to all. And the skill of one physician over another consists first of all in his quickness to perceive which organ he can most readily and most beneficially influence, to the ultimate benefit of its neighbours; and next in the extent of his armoury—the number of weapons, be they drugs or diets, which he has at his command, and the dexterity with which he can employ them.

In attempting to obtain a general idea of the circulation, and of the influence of the heart upon it, it is important to remember that no part of the cavity lying inside of the walls of the heart and blood-vessels is ever empty. We talk of the veins being empty when they are not so full of blood as usual; and we speak of the auricles and ventricles of the heart being empty when, by their contraction, the blood has been forced out of them. But, though the veins may collapse more or less, and the cardiac cavities may contract more or less perfectly, there is never within the heart or vessels any vacuity or empty space. The walls always closely follow

the blood when they contract, and when they dilate the blood closely follows them, and dilatation ceases at once whenever the blood ceases to follow. One important result of this is that there can be no muscular movement which does not favour the circulation in a twofold manner; first, by compressing the veins during muscular contraction, and so forcing the blood onward through the nearest valve on the cardiac side, closure of the valve on its distal side preventing its going backwards; and second, by some degree of aspiration which must take place during muscular relaxation. In like manner the diastolic relaxation of the cardiac cavities, especially the untwisting of the ventricles, must exert some degree of aspiratory or sucking force, and so aid in promoting the onward flow of the blood.

We must also remember that though the blood passes first through the right heart, then through the lungs, and lastly through the left heart, yet the two hearts are so combined that both auricles and ventricles dilate and contract simultaneously, presenting precisely similar phenomena. The two hearts, or rather the two halves of that complex organ which we call the heart, work together —in health—in all respects correspondingly and synchronously.

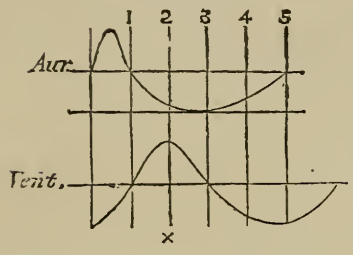
What we call one beat or pulsation of our heart is thus made up of a double series of events—that is to say, each

time that the heart strikes the wall of the chest, or beats, as we say, it indicates the completion not of one act, but of a double series of acts, each of which occupies an appreciable interval of time, some of them being revealed by phenomena which are recognisable by other senses than that of touch, being also accompanied by sound.

If we divide the period of one pulsation of our heart into five equal parts, then one of those parts represents the time occupied by the contraction of the auricles; two of these parts—two-fifths of one heart-beat—are taken up by the systole of the ventricles; the remaining period—also two-fifths—represents the diastolic pause common to both auricles and ventricles. The auricles, however, rest also during the two-fifths occupied by the ventricular systole, so that the auricles rest during four-fifths of each heart-beat, and work only during one-fifth of the time between one heart-beat and another; while the ventricles, in their turn, are in diastole during the one-fifth occupied by the systole of the auricles, so that they rest during three-fifths and work only during two-fifths of one entire pulsation of the heart. This will, however, be more readily understood by a reference to the accompanying diagram (Fig. 13, from McKendrick's "Outlines of Physiology"), in which the curve above the horizontal line represents the systole of both auricles and ventricles respectively, while the curve below the line represents

the diastole, the × indicating the apex beat. The apex beat is accompanied by a prolonged sound, called the first sound of the heart, and caused by the closure of the auriculo-ventricular valves already referred to (p. 19). The commencement of the diastole is also signalised by a short sharp sound, called the second sound, and due to the snapping together of the semilunar valves (p. 19). These sounds are readily heard on listening over the heart, either by simply applying the ear, or through a stethoscope, which, by more accurately localising them, enables us more certainly to separate the one sound from the other. Alterations of these sounds of various kinds are among the chief means by which the physician recognises lesions of the valves of the heart, which originate in many ways, and by impairing its mechanism tend to shorten life. Notwithstanding the popular idea, death from disease of the heart is by no means usually sudden, much more commonly the reverse; and perhaps it is even not too strong a statement to make that it is never really sudden, in the sense of unforeseen or without warning, and that there are comparatively few victims who have not suffered from their

FIG. 13.



disease for many years, and some for so many as from twenty to thirty years before its end. And indeed it is perhaps even a more important matter to remember that, by whatever disease originated, death always occurs from failure of the heart. The great function of the heart is to maintain the blood pressure within the arteries at such a pitch that the circulation may be duly carried on; for in order that there may be a circulation of the blood at all, it is absolutely necessary that one part of it—the arterial section which begins the round—should be at a higher pressure than the venous section, which terminates it. The tendency, however, of all the extrinsic forces concerned in the circulation, is to equalise the blood pressure throughout the vascular system, and so to bring the circulation to a standstill; and this is the way in which death at last occurs, whether it occur suddenly from mortal faintness, the result of bleeding, or more slowly from disease, the cause is still the same, cessation of the circulation brought about by equalisation of the blood pressure throughout the whole of the vascular system, or, as it may be otherwise put, from decline of the arterial (aortic) blood pressure. Having already learned the need there is for a due supply of nutritive fluid or blood in order to the manifestation of life, we can have no difficulty in understanding how its manifestations become feebler and feebler, and ultimately cease as the circulation gradually fails.

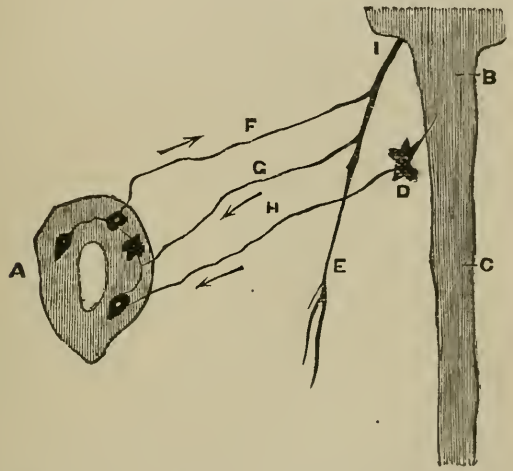
CHAPTER IV.

THE RELATIONS OF THE HEART TO THE GENERAL SYSTEM.

THE heart is united to every part of our frame in the close bonds of a sympathetic union by means of the nervous cords already referred to (p. 24). It is somewhat difficult to understand the manner in which this union is brought about, but its practical results are evident to every one, and are sometimes very alarming in their character. The accompanying diagram (Fig. 14, after Rutherford) gives a rough general idea of the anatomical elements concerned in the nervous control of the circulation. Certain ganglia are seen lying within the substance of the heart, A, and these are supposed to supply the automatic motor force which causes its movements. The action of these ganglia is controlled, first of all by a nervous influence coming from the sympathetic system through the ganglion D and along the nerve H, which is supposed to excite them to a more rapid and continuous exercise of their function. This nerve is called the *accelerator* of the heart; it is supposed to quicken the beat of the heart and to increase its force. Secondly, by an influence coming to the heart through G, a branch of the nerve I, called the *Vagus*, or wanderer,

because it is distributed to many organs—breast, lungs, stomach, and bowels. The influence derived from this source inhibits the action of the cardiac ganglia, slows the heart's action, and if acting powerfully it arrests the

FIG. 14.



A, the heart, with its ganglia, connected by two nervous cords, F and G, to the vagus nerve, and by one, H, with the cervical sympathetic ganglion, D; C is the spinal cord, and M the medulla oblongata or upper part of the cord which connects it with the brain—the arrows show the supposed course of the nervous force. (Rutherford.)

heart in a state of diastole or complete relaxation. Lastly, for its own protection, it seems reasonable that the heart itself should have some control over the circu-

lation through the blood-vessels, and this it is supposed to exercise through the nerve F, which seems to be only another branch of the vagus, but is regarded as really an independent nerve passing upwards in the same bundle with the vagus fibres. Through this nerve the heart is able to influence those centres in the medulla oblongata which regulate the movements of the arterioles, inhibiting or restraining their action, and in this way producing a paralysis or dilatation of the arterioles. The blood is thus permitted to pass more freely into the veins, the blood pressure within the arteries is lowered, and the heart, oppressed by an excess of work, is immediately relieved. A similar inhibitory influence is also propagated from organ to organ, regulating the local circulation, and consequently the secretions of the various glands. This system of checks and counterchecks, exercised on the circulation by antagonising influences propagated through the nervous system, permits of the temporary throwing out of gear, as it were, of any organ, so that secretion does not go on continuously but only as required. There is thus a great saving in the expenditure of energy, besides a great increase of comfort to ourselves. How miserable would our existence be, were our saliva always to flow as profusely as it does when the secreting glands are appropriately called upon; and though the expression "could our tears for ever flow"

may be highly expressive as a poetical fiction, the reality would be extremely inconvenient as a physiological fact.

The result of this nervous control of the circulation is not only advantageous from a utilitarian, but quite as much so from an æsthetic point of view. It converts what would otherwise have been the passionless monotony of our existence, into the scene of an ever-varying emotional display, which adds an otherwise unattainable zest to life, has proved a fruitful source of inspiration to poets and painters in all ages, and has even, strange to say, enhanced the monetary value of those exhibiting it; for it is said that the Sultans of old were wont to give a higher price for those Circassian females whose faces could light up with "love's own changeful hues," than for their less susceptible sisterhood.

Any emotion, be it pleasing or painful, love or fear, is only consciously realised through the medium of the cerebrum or large brain, and it is through the nervous connections subsisting between the cerebrum and the centres controlling the circulation that the distinctive phenomena of each emotion are produced. Not by any vague sympathy of the parts, as was formerly supposed, but by a distinct controlling influence conveyed to the nerve centres that regulate the circulation, which inhibits or stimulates them as the case may be, and which may

be successfully imitated experimentally. The coexistence of consciousness with emotion indescribably enhances the phenomenal display by combining with it the appropriate expression as revealed in the play of the features, the gestures of the limbs, and the light in the eyes. The intensity of the emotion is further indicated by certain subsidiary phenomena, which imply the persistence of an increased or diminished blood supply to the surface of the body, or to certain glands where secretions are correspondingly affected. Evanescent feelings of short duration only give rise to those

> "Playful blushes that seem nought
> But luminous escapes of thought,"

unaccompanied by any physical discomfort, except a slightly quickened action of the heart. But tears of vexation and a flush of heat are prone to accompany the blush of shame; while the bashful man, when he blushes, very soon gets not only uncomfortably hot but also moist with perspiration. It is not the face only that blushes in these circumstances, but the whole surface of the body is flushed and feels hot, while the heart beats with a violence proportionate to the intensity of the emotion. Blushing is often attributed to the exquisite sensibility of youth, which, according to popular belief, wears away with advancing years. This is the idea that strikes the gene-

rality of observers, and with this they are satisfied (Burgess). But the aged cheek can blush as deeply as the most youthful, upon adequate provocation. The blush of age is only rare, because long experience of the world gradually teaches us to estimate our surroundings, and the events that befall us, at more nearly their true value, and thus we cease to be so strongly moved by them. No mere physical cause can produce a blush; but when once a sufficient emotional cause has arisen, no effort of the will can arrest the resulting blush. When blushing, therefore, has become a painful habit, it is hopeless to attempt to check it by any opposition of our will; this only leads to signal failure, which is the more disheartening, the more powerfully we have striven to attain our end. The only hope of overcoming this objectionable habit lies in cultivating feelings directly opposed to those which give rise to it, so that the influence of the baneful emotion is opposed by a pre-existing antidote. As most of these cases arise from an overweening sensitiveness to the opinion of the world, it is desirable to cultivate such a moderately-good opinion of our own worth, wealth, or appearance as shall suffice to counteract this; and it is alleged that a free use of the Kilbarchan weaver's prayer, "O Lord! gie me a gude conceit o' mysel'," has occasionally been followed by the happiest results.

The sensation of fear is followed by very different consequences from those of the emotions just referred to. Juliet—whom no one could accuse of being cold-blooded—when about to take her sleeping-draught, and while youthful love and hope still lent their aid to cheer her, yet acknowledges that owing to her dread of what might happen—

> "A faint cold fear thrills through my veins
> That almost freezes up the heat of life;"

while Macbeth, whose antecedents at least, if not his character also, exposed him to the full force of such an emotion, exclaims to his wife when Banquo's ghost appears—

> "You make me strange,
> Even to the disposition that I owe,
> When now I think you can behold such sights,
> And keep the natural ruby of your cheeks,
> When mine are blanched with fear;"

and in another place he even more emphatically expresses the results of this emotion, saying—

> "This horrid image doth unfix my hair
> And make my seated heart knock at my ribs
> Against the law of nature."

Using words which recall those of an earlier poet, Virgil, who makes Æneas exclaim on meeting the ghost of his

beloved Creusa wandering through the blood-stained streets of Troy—

"Obstupui, steteruntque comæ, et vox faucibus hæsit"—

"I was amazed, my hair stood on end, and my voice stuck in my throat." 'Tis but a schoolboy quotation, but it supplements the others, and shows how fear in its results is exactly the counterpart of the warmer if not more exciting emotions. The surface is pale and cold, and the secretions dried up, making not only speech but even deglutition imperfect. We all remember the Indian method of detecting a thief, the pinch of rice given to each suspected person to chew in solemn conclave, the result being that he whose conscience has made him coward is at last forced to spit out his moiety, broken indeed by his teeth, but dry as he at first received it, the fear of detection inevitably bringing about the fact.

In these two classes of emotion, the influence conveyed to the centres controlling the circulation acts differently; in the one case the action of these is inhibited or paralysed, and in the other they are stimulated to more powerful action. We cannot by any physical agency produce these results and prove this fact; we cannot even physically reach these controlling centres without destroying the perfection of the mechanism; but we can do almost as well, we can attack the nerves passing from these

centres to the peripheral vessels of some transparent part, such as the ear of a rabbit, and by cutting them across we paralyse the muscular coat of the small arteries to which they are distributed, the vessels at once dilate under the pressure of the advancing blood-wave and the ear becomes red and hot; it is in a state of permanent blush. Now suppose we irritate or stimulate the end of the nerve which remains connected with the blood-vessels, which has all the effect of a stimulation of the nerve centres, the immediate result is that the muscular coat of these small arteries is thrown into a state of violent contraction, just as the muscle of an arm is made to contract by passing an electric current through it, the blood-wave is either completely stopped or so greatly diminished that the ear becomes pale and cold. From these experiments we are warranted in concluding that those emotions which produce blushing, inhibit or paralyse the nerve centres as effectually as if they severed them from the parts which they normally influence; while those which produce pallor stimulate these centres to increased action. The excited action of the heart, which so constantly accompanies powerful emotion of any kind, is partly due to alterations of the blood pressure within the arteries, a matter that naturally depends upon the greater or less readiness with which the blood passes out of the arteries into the veins, according as the arterioles are

dilated or contracted. But it is perhaps even more largely due to the direct influence of the emotion upon the heart itself, which, if it comes through the sympathetic, accelerates its action and produces palpitation; while, if it comes through the vagus, it arrests the heart's action, either temporarily producing an intermission or momentary stoppage of the heart, which may occur once, may recur several times, or may even give a new rhythm to the heart's action which may persist for days, months, or years, or which may prove suddenly fatal. This inhibition of the heart is readily observed in the frog, whose heart will beat for an indefinite period after all sensibility has been obliterated by destruction of the brain. The body of such a frog may be laid open without causing any pain or disturbance, and the heart will be found beating with perfect regularity. If we attach to such a heart a long index like a metronome, this will be moved backwards and forwards with every movement of the heart; and if we send an electric shock through the pneumo-gastric nerve of a frog so prepared, in one instant the index stops, and the heart lies motionless in diastole with all its cavities dilated; by-and-by its contractions recommence, and the experiment may be many times repeated (Huxley). In this simple way we gain the clue to intermittent action of the heart, and a knowledge of the mechanism of its production, invaluable as an aid to

prevention, and forming a very safe guide to appropriate treatment, is surely cheaply bought at the expense of a few frogs.

Excessive emotion has not infrequently proved suddenly fatal by inhibition or arrest of the heart's action, probably never in those whose hearts are perfectly healthy, but it has occurred sufficiently often in those who were not known to suffer from actual disease of the heart, though from their age or for other reasons that organ must probably have been to some extent degenerated. Though all excessive emotion is liable to this fatal termination, one would scarcely expect to find that unexpected joy is more dangerous to life than sudden grief; yet recorded instances of fatal joy are—according to Zimmermann, who has published a large collection of such cases—more frequent than those of death from grief. Sophocles, desirous of proving the full possession of his intellectual powers, which had been called in question, composed a tragedy when over ninety years of age, was crowned as the first tragic poet of the age, and died suddenly of joy. Manius Juventius Thalna, when decreed a triumph for having conquered Corsica, dropped dead from joy on receiving the intelligence. The famous Fouquet died suddenly on being told that Louis XIV. had restored him to liberty. The niece of Leibnitz died of joy on finding a box containing sixty thousand ducats below the phi-

losopher's bed; and there are a host of similar cases recorded, both in ancient and in more modern times, testifying to the fatal influence of sudden joy. Nor are cases wanting to prove that other and more depressing passions have an equally fatal result by inhibition of the heart. By a poetical license Shakespeare, speaking in the person of Marc Antony, represents the death of Julius Cæsar as occurring in this manner, and not from the daggers of the conspirators—

> "This was the unkindest cut of all;
> For when the noble Cæsar saw *him* stab,
> Ingratitude, more strong than traitors' arms,
> Quite vanquished him; then burst his mighty heart,
> And, in his mantle muffling up his face,
> Even at the base of Pompey's statue,
> Which all the while ran blood, great Cæsar fell."

Philip II. seems to have been a terrible monarch, for it is related of him that he killed two Ministers of State with the breath of his mouth: one he severely rebuked for answering him with some hesitation; the poor man dropped dead. To another, the Cardinal Espinosa, he said, "Cardinal, know that I am master!" the Cardinal was so terrified that he died a few days afterwards. Philip V. died suddenly on being told that the Spaniards had been defeated; his heart was found to be ruptured. Palmer, a well-known comedian, died on the stage of the

Liverpool theatre on August 2, 1798, while performing the part of "The Stranger," in the play of that name. He had recently lost his wife and a favourite son, and when, in the course of the play, one of the *dramatis personæ* asked for his family, in attempting to reply Palmer became inexpressibly agitated, and fell dead. Many similar cases have been recorded. Mallet's tale of Edwin and Emma, in which the latter dies suddenly of a broken heart on hearing of the death of her lover, was founded on an actual and precisely similar occurrence which happened in 1714 at Bowes, in Yorkshire. The expression "broken heart" is sometimes expressive of an actual fact—a diseased and enfeebled heart not infrequently rupturing under the distending influence of inhibitory dilatation. More often it is used figuratively, as when Shakespeare makes Malcolm say to Macduff, horror-struck at hearing of the murder of his wife and children,

> "Give sorrow words: the grief that doth not speak
> Whisper's the o'erfraught heart and bids it break;"

and then it means only that intense feeling of oppression at the chest, produced by emotional inhibition of the heart, identical with the arrest of the heart in diastole produced by irritation of the vagus, which may terminate in rupture if the muscular fibre of the heart be diseased, and which probably is never fatal even from inhibitory

dilatation alone, unless the heart has been previously diseased. At all events, no such case has been recorded within the last thirty years, since the diseases of the heart have been more carefully studied and better understood. When the emotional excitement has not been great enough to cause death by instantaneous and permanent arrest of the heart's action, its effects may vary from the more or less thumping and somewhat tumultuous action of the heart, of which we are all more or less conscious when momentarily alarmed, to a more persistent alteration of the heart's rhythm, which is then said to be *intermittent*, because the momentary inhibition of the heart causes a failure of the pulse at the wrist which is technically called an *intermission*. This intermittent action of the heart is sometimes accompanied by an uneasy sensation within the chest, and at others it is wholly unnoted by the sufferer. Anxiety, grief, terror, violent anger, or excessive fatigue, have all been noticed as occasional causes of this intermittent action of the heart. And it has been remarked that the ultimate results have varied according to the violence of the emotion on the one hand, and the sensitiveness of the organism on the other; so that in some individuals the result dies off with the fading of the emotion which produced it, an intermission which has at first occurred once every two or three beats,

and has been accompanied by great uneasiness, gradually dying off till it occurs only exceptionally at long intervals, and is wholly unnoted by the patient except as an objective phenomenon; while in others the disturbed rhythm of the heart persists as a fact of which the sufferer cannot for one instant lose the consciousness, and which ultimately wears him out by the silent but terrible and sleepless suffering it produces. When the individual has been fairly robust previous to his exposure to some cause of sudden overwhelming emotion, the most common result is a gradual and complete disappearance of the unnatural rhythm, the only remanent trace of inhibitory derangement being shown by an unnatural proclivity to a return to an abnormal rhythm upon very slight provocation.

Fatal inhibition of the heart may, however, arise from other causes than emotion; cold to the surface or to the stomach are quite common sources of fatal cardiac inhibition, while the ingestion of indigestible food is the most common cause of all. Not a summer passes that some are not said to be drowned by being seized with cramp; they have indeed neither been seized with cramp, nor drowned; the individual dies at the moment when, swimming easily about, he suddenly throws up his arms and sinks to the bottom, the pulsation of his heart fatally arrested by the inhibitory influence of cold propagated from the surface of the body. Infants sometimes die in the same

way from the shock of a cold bath. Taken into the stomach cold water even more readily excites the fatal inhibitory influence of the pneumo-gastric nerve; scarcely an autumn passes without there being one or more deaths in the harvest field from this cause; and it has been alleged that Alexander the Great lost more of his men from drinking the cold waters of the Oxus than from all the battles which he fought during his Eastern campaign. But of all the causes of cardiac inhibition, the most common of all, and fortunately as a rule the least serious, is the irritation produced by a little wind in the stomach (flatulence), or by some undigested food, both of these causes being often associated, as the one is a most common result of the other. Indigestion, comprehensively understood and from whatever source arising, is thus the most frequent cause of intermission of the heart's action. The sufferers indeed scout this idea; they never have a headache, are never sick, have always a good appetite, and can eat anything they please with apparent impunity, so far at least as the stomach is concerned. True, their indigestion affects their heart and not apparently the stomach, but we know that this is not really the case, and that the heart is only affected secondarily. And even in those cases which have to all appearance the least connection with the stomach, a careful attention to it, with strict regulation of the diet and other appro-

priate remedies, will often be attended by the happiest results.

Sometimes the cardiac inhibition is not powerful enough to arrest the heart's action even temporarily; it merely weakens it: the pulse falters, beats feebler than usual for a time or two, the heart being simultaneously felt to flutter, its ventricular contraction is not arrested but merely enfeebled, and its action is not intermittent but merely *irregular*. *Palpitation*, on the other hand, is simply an unusually rapid action of the heart, sometimes purely emotional in its character, and then commonly of but short duration, while at others it arises from some physical or inflammatory irritation, and then it is more permanent in its character, and may persist for many months. These modes of perverted action of the heart, though troublesome and sufficiently alarming to the sufferer, are rarely indicative of any real danger, though they usually betoken an exceptional degree of irritability of the cardiac muscle as well as of nervous mobility, a state of matters which, if associated with actual disease, may cause them to be more or less serious complications.

Our present organisation is such, that if one organ suffers the others suffer with it; to the ignorant, these sufferings are often eccentric, *bizarre*, and incomprehensible. Thus, decayed teeth may produce blindness or a neuralgic shoulder-joint, a worm in the bowels may give

rise to a most troublesome cough, and flatulent dyspepsia may only reveal itself by the most extraordinary vagaries on the part of the heart.

Though weak hearts are more liable to have their action perverted by ordinary causes, yet if the exciting cause be a powerful one, the very strongest heart will hardly escape. This is the penalty we pay for our present state of being; it is the result of our having a nervous system which not only helps us to all enjoyment but which is also incidentally the cause of much suffering, yet without which our organism could not exist for an hour.

CHAPTER V.

HOW TO MAINTAIN THE INTEGRITY OF THE HEART'S FUNCTION.

When we consider the importance of the heart's function to the maintenance of life, and the vast amount of work which the heart performs in the discharge of this function, not for one hour, one day, or one year, but for seventy odd years unintermittingly, we can understand the importance of some little care on our part to maintain its pristine vigour as long as possible, and to ward off all injurious influences to the best of our ability.

We have learned that though the heart could send the blood through the body like a great bore-wave, rushing from left ventricle to right auricle, yet it does not do so, things being so arranged as to make its great function merely the maintaining of such a continuous pressure within the arterial system as to secure the onward flow of the blood, so that when the nervous system—which holds the keys of all our wants—opens the sluices in any one direction, the blood may flow in at once with such force as will allow the gland to functionate actively, no other part of the body suffering. When this is the case we possess all the delightful energy of perfect health; we can think clearly, walk without fatigue, and digest our food without trouble; all of course in moderation, because our organs need to be rested and repaired, and there is no other organ but the heart which takes both its food and its rest by the way as it were, in short snatches during its period of action (*vide* p. 33). When the circulation, however, is languid and feeble, everything is reversed, every act of life is more or less imperfectly performed, and its performance is accompanied with more or less discomfort. In this state we are not necessarily ill, but neither are we well, and we are little able to resist the thousand ailments to which we are continually exposed; the germs of zymotic (febrile) or parasitic disease find a suitable and congenial soil in the slowly and im-

perfectly renewed—and consequently enfeebled—tissues. Nay, the very imperfectly renewed tissues are themselves a source of disease; the impure blood may be either rheumatic or gouty, and besides giving rise to many symptoms of disease peculiar to itself, it may seriously modify every phase of life, whether actually morbid or apparently healthy. With impure blood supplied at a low pressure every gland must of course secrete unhealthily, both as to quality and quantity; and at the best the unhappy individual lives in a vicious circle, from which he can only emancipate himself by slow degrees and by careful accumulations of trifling advantages. In this condition there is defective energy, life is poisoned at its springs, and the unhappy victim leads a more or less ailing life, prone to many diseases, unable to resist any effectively, and, unless his health is improved, his life is ultimately shortened by one or other of these organic ailments which necessarily arise from his state of abnormal nutrition, and in which the heart plays no unimportant part.

It has been already stated that it is by the more gradual, or by the sudden lowering, of the arterial blood pressure that death occurs in every form of disease. It can be readily understood, therefore, that the condition of the great central organ of the circulation is an object of anxious interest in all serious febrile or inflammatory

disease, and that the feeling of the pulse is not a mere form; while, though its rate is not an altogether unimportant matter, its force and character are of very much greater consequence, inasmuch as they are truer indications of the state of the blood pressure, and consequently of the heart.

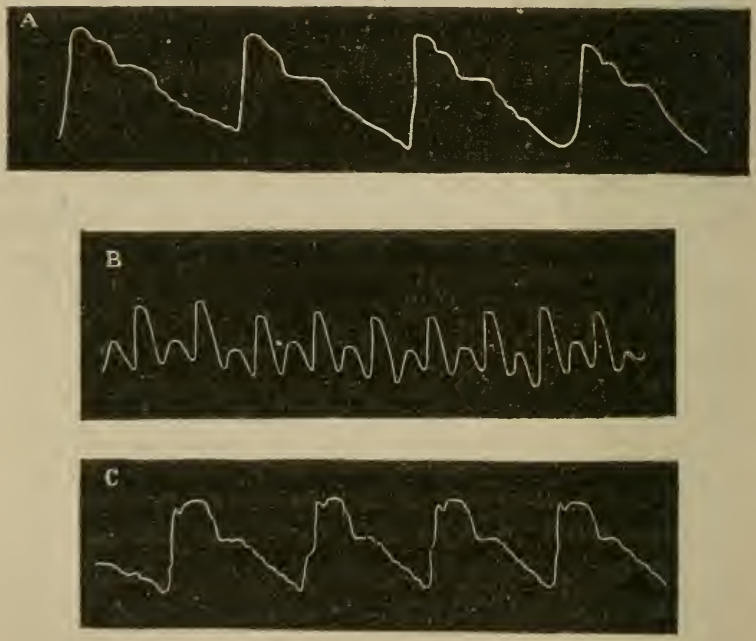
The blood pressure signifies the state of arterial tension, and is made up of three factors—the amount of blood in the arteries, the strength of the heart's contraction, and the state of the arterioles—that is, the greater or less readiness with which the blood escapes from the arteries into the veins. If either of these factors fail, the blood pressure falls, the circulation is only maintained with difficulty and after a precarious fashion; whether it can ever be again restored to its positive state of security depends very much upon the cause of the change which has taken place. The change itself is readily appreciated by the educated finger, but the outline of the blood-wave passing through the arteries is sufficient to make this change obvious to the most uneducated eye. This outline we usually obtain from the artery at the wrist, where the pulse is commonly felt, by means of an instrument termed the sphygmograph, or pulse writer; and the appearance of the tracing, from arteries in different states of tension, is sufficient to show to the most ignorant that different conditions are present, though considerable

explanation would doubtless be required to elucidate the causes of these varying conditions, as well as the manner in which their respective characteristics are impressed upon the blood-wave and its tracing. When the blood pressure is at a minimum from failure of the heart, the resulting blood-wave is only able to trace a slightly undulating, almost straight line. The normal blood-wave gives a bold tracing of a somewhat peculiar form, such as we find at *a* Fig. 15, the upright stroke of which represents, by its height and mode of junction with the descending oblique line, the fulness and force of the heart's contraction; while the obliquely descending line indicates, by the number and form of its undulations, various particulars as to the state and tension of the arterial wall. Fig. 15 *b* represents a tracing of the dicrotic, or doubly beating pulse common in many diseases, and capable of being artificially produced by the administration of those drugs which paralyse and dilate the arterioles; it indicates, therefore, a blood pressure below the normal, due rather to too free an escape of the blood from the arteries than to failure of the heart power. And Fig. 15 *c* is a tracing from an artery in quite the opposite condition; one in which the tension is increased because the arteries generally have lost their elasticity, and the blood cannot get so freely away as it ought. This is a condition which occurs after middle life more or less in all, and is the

most common cause of disease of the heart in elderly people.

When the blood pressure falls, there is a risk of death

FIG. 15.



occurring in no long time from gradual cessation of the circulation; it is important, therefore, to recognise this

condition early, in order that appropriate measures may be employed to remedy it, and by timely stimulation of the heart we may be enabled to rouse its energy, and thus rally the patient from an apparently desperate condition, and thus save a useful life. A rise in the blood pressure is rarely an indication of immediate danger; more commonly this is remote; but it is not less our duty to forestal possible evils, and by appropriate remedies, and, in those cases where it depends upon loss of arterial elasticity, by a wise guidance of all our future life, we must endeavour to avert the failure of the heart's force. By so doing we shall very often be able to maintain a very considerable degree of comfort, and shall at all events be able to postpone the inevitable end. But all this belongs to the history of medicine proper, while here we have only to do with the prophylaxis, or art of warding off disease of the heart—a subject of sufficient interest, seeing that, even from the comparatively limited point of view of the Registrar-General, it involves an annual mortality of 30,000 in England and Wales alone, being one-sixth of the total annual mortality; while from a pathological point of view a very much greater number indeed owe their death to lesions which, if not all strictly cardiac in their origin, are yet truly diseases arising in the circulatory apparatus, and owing their fatal progress directly to cardiac failure, though reckoned under

many various heads; and in this calculation all febrile or inflammatory diseases are excluded.

The further consideration of this part of our subject may be very profitably pursued under the several heads of childhood, youth, middle age, and old age.

Even before birth the heart may be so irretrievably damaged by arrest of development, or alterations produced by disease, chiefly of an inflammatory character, as to make independent life much more truly one long disease than it is so often represented to be—even at its best. Between the short span of a few hours, which is the limit of life to most organisms so imperfectly developed and the nominal existence of seventy odd years, there is a wide range, any part or even the whole of which may be attained by those labouring under congenital disease or malformation of the heart. Of course the larger proportion of those with congenitally malformed hearts die within the first few years of infantile life; still a certain proportion linger on till adult life, and of these a small percentage attain even an advanced age; and many of those who reach this advanced age present such very evident indications of there being something wrong, as help to prove in a most remarkable manner how impossible it is for the non-professional eye to judge of relative imperfections in our internal organs, or to apportion vitality according to appearance. Apart from

these congenital defects, the heart suffers during childhood from inflammatory affections attacking the chest, especially when the left side is affected, many cases of disease of the heart being apparently traceable to such diseases occurring in early infancy. Febrile diseases, of which those occurring during childhood are chiefly of the exanthematic type, such as measles and scarlet fever, though rheumatic fever also occurs even in infancy, and other diseases such as whooping cough, are all capable of more or less seriously damaging the heart, and convalescence from such diseases must be always anxiously watched, though such is the great degree of vitality present at that early age that it is comparatively seldom, except in the case of rheumatism, that any serious damage is incurred.

After the sixth birthday the period of youth or adolescence may be said to commence, and this may be regarded as continuing to the twenty-fifth year, when the frame is usually set and the long plateau of middle life commences, which might itself be divided into three epochs—early manhood 25–35, middle life strictly speaking 35–45, and commencing age 45–55, after which old age may be regarded as beginning, though in some it advances but slowly.

The period of youth is that which is fraught with most peril for the heart, those who have escaped the exanthe-

mata during childhood are almost sure to be attacked on commencing school life; greater exposure increases the risk of severe rheumatic attacks. Chorea, in the course of which the heart is invariably more or less affected, now for the first time invades the frame. And besides all these, we have the serious calls made on the constitution during the development of the organism, in the course of which the heart is only too apt to suffer, and we have also a certain amount of risk of injury to the heart incurred during those gymnastic exercises in which youth is so prone to indulge.

It is right to put on record all those multifarious forms of disease in course of which the heart is apt to get damaged, because the mere cataloguing of them may be a means of keeping in remembrance evils that may be consequent, and, by directing attention to the possibility of their occurrence, may be the means of preventing their unobserved advance to an irremediable maturity. But it is also right to remember that all these ailments by which the heart is damaged can only hinder the due performance of its functions by injuring the perfection of its mechanism. This injury to the mechanism of the heart may, however, be brought about in two ways: first, by injury to the valves; and second, by weakening of the cardiac muscle, and this weakening of the cardiac muscle may itself result in valvular imperfection, but one which

at all events at first is of a curable character. There is but one disease which always produces incurable valvular deformity, and that is endocarditis, inflammation of the lining membrane of the heart; and this may be of an acute, subacute, or chronic character; extremely often it originates in rheumatism, sometimes in pregnancy, very often in gout, and less frequently in syphilis and injury. By-and-by we shall consider the prophylaxis of these affections.

Debility of the cardiac muscle is a much more frequent source of cardiac discomfort, and a much more common cause of actual cardiac disease, than is supposed by most people, and though fortunately disease thus produced is frequently of a curable character, it is still more fortunate that by judicious care such affections can be to a large extent wholly prevented.

All affections of the heart, whether curable or incurable, which arise from debility of the cardiac muscle ultimately resolve themselves into what is termed a heart-strain. When any muscle is called upon to make an exertion greater than it is capable of, it is either strained or ruptured; a strain involves of course, as we all know, incapacity for perfect contraction for some time, and to a hollow muscle like the heart this of course involves dilatation. So that a greater or less degree of dilatation of the heart is the natural result of every heart-strain, however slight.

A heart-strain may arise from violent over-exertion at any age, and is usually more or less serious, according to the age of the individual; serious in its immediate as well as in its ultimate results.

What we call fatigue is merely an indication that the muscles want rest; the transformation of energy has been so great, and so continuous, that the ordinary blood supply is insufficient to keep it up at the same rate; the muscle must, therefore, rest, and it indicates this to the consciousness of the individual by sending through its sensory nerves a feeling of fatigue to the sensorium. The heart never gives any indication of fatigue beyond an excited and laboured action; but, if violent exercise be continued after this indication is given, the overladen heart gets over-distended, sends an insufficient supply of blood to the brain, and the victim falls to the ground, incapable of any exertion greater than that involved in the bare maintenance of life. This sudden heart-strain may follow any violent exertion, such as running, rowing, or lifting heavy weights; and, after middle life, when the tissues of most people begin to deteriorate, the results may be very disastrous, and even fatal. A similar accident may also occur in early life, but seldom, and it is rarely serious in its character at that age. But in a lesser degree, and of slower development, heart-strains are a very common source of cardiac discomfort in early life,

and may even end in the development of serious disease. This is one of the risks to which young and growing lads are exposed when they engage in athletic sports without due preparation, and it is town-bred lads who are most apt to suffer in this way. A country boy is always on the move; his tissues are thoroughly nourished and well developed, and his blood is full of oxygen, so that he is well prepared for any exertion. A town-bred boy, on the other hand, has his muscles less fully developed; his blood contains less oxygen, and there is more fat about him; he more easily gets blown and fatigued; he therefore runs a greater risk of heart-strain on first commencing football, cricket, or rowing, than the more fortunate denizen of the country, simply because his cardiac muscle is weak, and therefore unfitted to resist the strain thrown on it. But all this can be put right by a little judicious care on the part of those in charge to see that the youthful enthusiasm of the boy is restrained until by gradual training he has become fitted for taking part with his fellows. Perhaps in these days it is even more necessary to put in a plea for the girls, that they should not be permitted to injure themselves by desultory over-exertion. A girl who perhaps never brushes her own hair, or is tired to death with doing it, is yet permitted to ride till over-fatigued, perhaps as a means of refreshment after dancing half the night; to skate all day,

or to play lawn tennis, not always on a lawn and in the open air, and to carry it on far too long in all the excitement of a match. Can we wonder that hearts so over-excited get strained, dilated, or irritable, and that the very means intended to promote health and strength become a source of weakness and disease from which recovery is always tedious, because the exertion is desultory and excessive. No man would permit his racehorse, his greyhound, or even his pointer, to be so abused; is his daughter or sister of less value, or are human frames built upon different principles from those of other animals? It is well to remember, too, that similar causes have similar results at any age, and that when a city merchant, a lawyer, or a member of any other profession, leads a sedentary life, or at least one of comparative inaction during ten months in the year, and goes North to his deer forest or his grouse moor for the other two, he does so at considerable personal risk. A comparatively young man of good constitution, who has been in early life a public schoolboy and accustomed to indulge freely in all the usual athletic sports of school life, and has lived temperately, runs the least risk. Even for him these risks gradually increase, and after middle life are very considerable, and they are largely augmented by habits of self-indulgence, or by the presence of a gouty or other depraved habit of body, especially if that be

hereditary. And the risk is not so much one of the sudden development of serious heart-strain, though that too is not impossible, but rather consists in the starting of a form of heart-strain of slower development, though of not less serious character, which is but the beginning of the end. Every man, therefore, who is not in training, that is, who does not walk smartly at least ten miles daily —and mere hanging on the feet or dawdling along the street counts for nothing in this respect, however fatiguing they may be—ought to be specially careful when he commences his work on his moor, even if he be under middle age; while if he be over middle age he ought not only to be specially careful, but he ought also to take medical advice as to the state of his circulatory system, before he ever dreams of any sport higher than a battue, or its analogue, a grouse drive. And of course the same remarks are applicable to any other form of violent exercise only occasionally indulged in during intervals of leisure, whether the special form be Alpine climbing, salmon fishing, rowing, or cricket. The risk consists in the occasional character of the indulgence far more than in the form of exercise, and it is largely increased even by the use, and still more by the abuse, of alcohol and tobacco, which have a direct enfeebling action on the heart that may be seriously injurious unless kept in the strictest moderation. It is well,

too, to remember that a mistake in early life, if taken in time is easily recovered from, but the older one grows the more difficult this becomes, until a period arrives when all we can do is to put on the drag so as to delay as much as possible the approach of the inevitable end. This period comes early to some, even before middle life; to most it arrives about middle life or in early age, while there are a very few exceptional individuals who never seem to age at all as regards their circulatory system, and who die apparently from accident often at a very advanced period of life.

There is also another danger to which the young are liable, even when care is taken that no undue risk is run in commencing athletics, and that is in making them too violent and continuing them too long so as to develop an enlargement or hypertrophy of the heart. This is not of frequent occurrence, and as a rule on giving up athletics it gradually dies off, and the heart returns to its former condition.

Some, however, of the most serious affections of the heart in the young are apt to come on in a most dangerous and insidious manner from malnutrition; both sexes are liable to disease arising in this way, coming on either after one or other of the febrile diseases of childhood, or arising from simple exhaustion due to defective nourishment of the body during the development of

puberty; and in this respect the female sex are the greatest sufferers. Having learned the amount of work that the heart has to do, we can readily understand that it suffers greatly from any interference with the general nutrition of the body. If the external muscles of the body are wasted and flabby, the heart cannot but be more or less limp and flaccid, and any loss of tone is immediately followed by some degree of change of structure: early recognised and taken in time this may be of no consequence, but if neglected, serious and incurable diseases may be the result. How often is this the case! some delicate girl has been encouraged to go about when quite unfit for exertion, with the view of improving her health, and the result has been that, warned by a greater degree of breathlessness than usual, or by some unwonted puffiness of the ankles, her friends have at last taken medical advice, and well it is for her if they be not too late. Even yet, with all our advances in the knowledge of morbid processes and their treatment, too late is still a possibility; how many such cases were formerly allowed to lapse into incurability it is impossible to say; many did so, fortunately not all, for in the spring-time of our life there are but few of what we may call the nutritional diseases which may not be thrown off by a moderately robust constitution under favourable circumstances. But there is equally little reason to doubt that

judicious treatment is able to shorten the period of risk even for these favourable cases, as well as to rescue many others from life-long misery. Help in time is certainly able to relieve much uneasiness, to lessen the risk of the affection becoming incurable, and in the worst cases it will greatly improve the health of the sufferer and prolong his life. The watchful care of the parent should not, however, wait till the heart is actually affected before it takes alarm; the olden motto, *obsta principiis*—withstand beginnings—of evil especially, should be remembered, and the first indications of failing health ought to sound a note of warning to be acted on at once. Pallor, languor, failure or capriciousness of appetite, or any inability for the ordinary enjoyments—to say nothing of the labours—of life, ought always, but especially in young people, to be regarded as important indications of a failure of health, the cause of which should be most carefully investigated and remedied. If this be not done at once, the best that can happen is the production of an impoverished condition of blood, a weakened and more or less incompetent heart, an enfeebled frame, and a delicacy of constitution which may last for years, and which, if not detected and remedied, may not only lay the foundation for serious organic disease, but may also give serious or even fatal efficacy to any accidental ailment which may attack the patient in the meantime.

How often do we hear it said, "Oh, there is nothing wrong; the heart is only a little weak, or the blood a little poorer than it ought to be;" words apparently of but little moment, but of ominous import to those who know that the integrity of every function of the body depends upon the maintenance of a due amount of intra-arterial blood pressure, and on the quality of the circulating fluid. For the heart is an organ which rests only in sections, and for fractions of a second at a time. The work done by it is not only continuous, but, relative to its size, it is greater than that of any steam engine in the world. Unless, therefore, it is kept in the most perfect repair, the mere strain of its own work is too much for it; it becomes mechanically unfit for the discharge of its function, and we have all the untoward results which flow from such a state of matters. The heart, however, is kept in repair by the blood, which removes its waste and supplies it with fresh material. But if the blood is in any respect poor or imperfect in quality, all the organs of the body suffer in their nutrition and in the energy with which their functions are discharged; and the heart suffers earliest of all, because of the nature and amount of work it has to do. Poor blood thus means a weak heart, and that involves the imperfect discharge, not only of the heart's own function, but of all the other functions of the body, one result of this being the reproduction of

poor blood. We are thus in the midst of a vicious circle, from which the organism cannot free itself without extraneous help, and though that help may be given in various ways, it is most surely attained through the wise counsel of a skilful physician. But though impoverished blood and a weak heart may, and occasionally do, result, when neglected, in permanent cardiac disease, they are even more serious from the lowered vitality of the organism which they induce, a condition which not only causes many influences to prove injurious which would otherwise be harmless, but which makes the organism less able to cope with any injuries it may receive, and more liable to succumb, and which, even at the best, deprives it of that bodily and mental energy needful to ensure success in the battle of life. The health, the bodily comfort, and the future success in life, all therefore require that careful attention be paid to the maintenance of a stout heart and good blood in the rising generation, for without these there is neither any certain health possible nor any sure success attainable.

It is not always very easy to say what is the beginning of all this evil, there are so many various ways in which constitutional exhaustion may commence, all of them insidious and growing apace, though too often unmarkedly, till suddenly a breakdown occurs, and then the

heart is certain to be found affected, fortunately not incurably so, except in a small minority of cases.

It has been already pointed out (p. 8) that every act evincing life is the result of the transformation of potential into kinetic energy, and that the object of the circulation is to remove waste and provide for such a renewal of tissue and of oxygen as to maintain the normal amount of potential energy within the organism. To maintain this standard of vitality, the income of the body must at least equal its expenditure, otherwise bankruptcy of health will as surely follow as would bankruptcy of means a similar state in regard to money matters. By the *income* of the body is meant all that the body receives in the shape of food, drink, and oxygen in the course of the day, while the *expenditure* is of course the waste incurred in the transformation of energy. This may be calculated from the various excretory products of the body, and has been thus ascertained to be for a healthy adult between seven and ten pounds in the twenty-four hours, including solids, fluids, and gaseous matter (oxygen). To provide for this waste, which consists almost wholly of oxidised material in solution, a similar amount of unoxidised material, with sufficient water for its solution, must be supplied through the stomach, and an appropriate amount of oxygen through the lungs. There is no difficulty about the oxygen;

that is supplied by the air by the natural process of respiration, the cessation of which is productive of such disagreeable results as are never voluntarily endured for long. But the ingestion of the solids and fluids necessary for our maintenance is so dependent on our own will as to lead to the most extreme variations, both in regard to excess and deficiency, and each of these extremes is productive of very injurious results on the heart, and through it on the system at large. If our income just balances our expenditure, this has a very different signification at different stages of life; at all periods it means a precarious hand-to-mouth life, without a margin to draw upon in case of illness. In youth, when the body is being developed, a defective income, that is one no larger than the expenditure, signifies even more. It signifies defective growth, and as the result of that, an ailing life, which may, if not remedied, terminate in irremediable disease. In middle life and old age we have no further development to provide for, but neither have we that to draw bills upon. Our expenditure dare not therefore be so great in relation to our income as in youth. And if we have no margin of potential energy laid up in store, we readily suffer from a thousand ills, which are utterly harmless to a man with a margin; and though our future may not suffer, our present is always more or less precarious. There is no longer any risk

of stunted development, but any accident may suffice to fatally lower a blood pressure already only at par. For a healthy adult man taking full exercise, a diet consisting of $2\frac{1}{2}$ lbs. of solid food, of which from $\frac{3}{4}$ lb. to 1 lb. may be animal food, and three pints of liquid—water, cocoa, or tea—is amply sufficient; while, though some certainly do live and maintain an appearance of health upon much less, yet twenty-four ounces of solids may be reckoned the lowest limit even for those who do nothing but beg, while for those who actively work the amount must be considerably increased. It has long been known that those who are starved are not long of losing their sense of hunger, because exhaustion, however it may arise, blunts every sense, hunger amongst the rest; but we seldom reflect that though starvation is a relative term, it may have a similar effect, however it may be brought about, and yet it is needful to remember this, for it has a most important significance. Youth is the period of superfluous energy, but it is also the time when growth is going on, to provide for which we require an excess of nutritive material, part of which is temporarily stored, providing that excess of potential energy just referred to; but if we waste this needful excess in undue indulgence in athletic sports, even in such apparently mild forms as in taking too long walks, in over-much brainwork, or in excessive emotion, our

expenditure becomes relatively greater than our income, and all the results of starvation speedily follow. Amongst these are a greater or less loss of appetite, blunting of the sensation of hunger, either an absolute disinclination for food or drink, or, at all events, such an aberration of the sense of hunger as leads those afflicted with it to fill their stomachs with whatever they may fancy, however indigestible, rather than with wholesome food. The result of this is easily foreseen, the composition of the blood is speedily and materially altered for the worse, and of course the heart quickly suffers, and with it the whole organism. It is only by slow degrees that all these important changes occur, and although when once they are fully developed and attract attention it may be impossible to carry their history backwards farther than a few weeks, yet we may be assured that the progress of such affections is very slow, and as it is also comparatively easily checked at first, those in charge of young people ought to be very watchful. We are so apt to regard joy or sorrow as mere feelings that we forget that these feelings have a physical basis, and that their perception is an expenditure of force. Grief, too, has a depressing influence of itself, which, as we all know, takes away our appetite, and when to this loss of income we add the additional expenditure occasioned by those sensations by which we recognise its existence, and

reflect upon the consequence of a disturbance of the proper relation between income and expenditure upon the constitution of the blood, and through that upon the heart, we know that the poetical phrase "a broken heart" is no mere fiction, but merely an exaggerated statement of what actually occurs, the term "o'erfraught heart" being strictly, and even pathologically, correct. But excessive emotion is not the only expenditure of nervous force in regard to which we should be watchful. Over-study is a more widespread and destructive evil, and in these days of competitive examinations it is a most destructive one. While the idea of counteracting the evil effects of prolonged brainwork by a bout of violent athletics is one arising out of the notion that brainwork is no expenditure of income, but merely a nervous excitement, mainly injurious by its preventing the working off of that food which our stomach insists upon having. The moment, however, that we realise that brainwork is as great, and in some respects a greater, expenditure of income (food) than muscular exercise, then we comprehend that to counterbalance prolonged brainwork by violent exercise is to burn the candle at both ends, and is as certain of producing bankruptcy of health as the latter figurative procedure when exercised in regard to money matters is of producing a similar condition financially. It is a most important fact

to remember, that all emotions, such as grief, unrequited affection, and all over-exertion, either of mind or body, all of which are equivalent to excessive expenditure, may produce, *even amidst abundance*—and it is this which it is important to remember—all the effects of starvation, and the result of that is not hunger. Dr. Kane says: "It is curious that the effect of short allowance does not show itself in hunger. The first symptom is a loss of power, often so imperceptibly brought on that it becomes evident only by accident." And a mechanic, when asked how the children got on during the cotton famine, stated, as part of his reply, "When their blood got thin, puir craturs, they were a mair easily pleased, for they didna feel sae hungry."

Remember, then, that excess of expenditure over income, however produced, by excessive emotion, mental or bodily exertion, always results in impoverishment of the blood; that this is speedily followed by impairment of the heart's structure and of its function, as well as by general degradation of the organic health, which lays us open to a thousand ailments, and is specially apt to result in organic disease of the heart. And we must never forget that in the world of Hygeia, as well as in that of finance, the care for apparent trifles results in the accumulation of a reserve of potential energy, and that one of the greatest obstacles to improvement is to be found in the

obstinate manner in which the organism persists in ignoring its own danger.

Those affections of the cardiac function dependent upon spanæmia, or impoverished blood, are all curable if taken in time and properly treated; they are therefore usually called functional, as if they related only to the function of the heart, and did not also implicate its structure. But we know now-a-days that the physical signs upon which we rely for the detection of these affections have always a similar physical basis, whether the affection is curable or not, and we employ the word functional only as an indication of our opinion of the curable nature of the disease. Functional diseases of the heart are all diseases of early life, only occurring exceptionally after adult life has been fully attained, and only rarely, and when neglected, giving rise to serious organic mischief. The most frequent cause of organic disease of the heart is, however, also a disease of youth—RHEUMATISM. In our ignorance we no doubt include under this head, that is to say, we are apt to refer to some unknown preceding attack of rheumatism, many cases of organic disease of the heart which have really originated in non-rheumatic inflammatory attacks of a chronic or subacute character, but even after making a large allowance for such mistakes, rheumatism is still left *facile princeps* as the curse of mankind so far as disease of the heart is concerned. And it

is specially so in this, that it is not a wasted or worn-out life which it shortens, possibly mercifully, but it is the young, the strong, and the apparently healthy that it seizes upon, and forthwith poisons all their springs of life. It is truly sad to see mere children in all the innocence of childhood, young men and maidens in all the beauty and the pride of youth, crippled by the fell destroyer, not killed but scotched, and doomed to lead henceforth a lingering life in death. This, however, is rather the professional aspect; to the sufferers themselves the case for the most part seems neither so sad nor so hopeless. Some no doubt suffer greatly, but many get along not only pretty fairly, but without any conscious embarrassment for many years, liable no doubt, as we all are, but such sufferers in a much higher degree, to sudden death, yet fully able to enjoy life like their neighbours till a period comes when the dynamic compensation fails and "earth goeth to his earth, sooner than it would," or ought. What proportion exists between those who suffer greatly and die early, and those who make out without discomfort a fair proportion of their span, is as yet unknown; but, be this as it may, there can be no doubt that if we could annihilate rheumatism we should prevent an almost incalculable amount of misery and suffering arising from secondary disease of the heart. Even by shortening the duration of the attack we do something towards this

prevention, though not all that could be desired. Modern physic has taken a great step in this direction; but unfortunately implication of the heart is so often an early complication of this disease that the speediest cure could not totally prevent its occurrence, consequently our only hope of this lies in the total extinction of the disease. A hopeless task, some may say, to seek to extinguish rheumatism; but many diseases have, during the lapse of ages, apparently changed their character, and some have died completely out, and why should rheumatism prove any exception? Why should the science of the nineteenth or the twentieth century be unable to do for rheumatism what chance and haphazard have done for other diseases during former ages? Unfortunately so little is known about the actual causes of this disease that as yet we scarcely know where to begin. If we were to follow the popular view, all that seems to be needful is only to avoid cold and damp, to clothe warmly, feed well, and secure a dry and comfortable house, and we have done all that is possible. But those who know that the class who suffer most from rheumatism are young servant girls, brought from running half wild on the hillsides to a warm, comfortable town house, and from the scanty fare of their cottage home to the plentiful and even luxurious table of the servants' hall, may be permitted to doubt if warmth and good feeding are the only requisites to ensure immu-

nity from rheumatism. And this doubt is not lessened when we find that Dr. Haviland in his great work on the 'Geographical distribution of heart diseases and dropsy in England and Wales,'* points out that those districts which have the lowest mortality from such diseases are amongst the most open and exposed in the whole country, while many of those districts in which the mortality from such causes is highest are the most sheltered spots in the country—valleys to the leeward of sheltering ranges of hills, or towns with streets so constructed that no rude or boisterous blast shall penetrate them. Dr. Haviland has published a large map exhibiting in divers colours those districts having the highest and those having the lowest mortality from heart disease and dropsy, presumably of rheumatic origin, as ascertained by his own inquiries in relation to 236,983 deaths occurring during the decade 1851–60. And he recommends those convalescing from rheumatism to avoid all those localities having a high death rate from heart disease, when they are selecting a place for change of air; and he also advises all those whose family history indicates a proclivity to rheumatism to choose for their permanent residence such localities and districts as experience has shown to have a low mortality from the secondary results of this disease, if they wish to avoid evoking a disease to which their

* London, 1875. Smith, Elder, & Co.

constitutions are already only too prone. To gain immunity from rheumatism, were it possible to do so, would be worthy of almost any sacrifice, as it is a disease which mainly attacks the young, and so often cripples the very citadel of life as to poison all its springs when it does not actually cut it short. Still it is not possible for many of us to pitch our tent in this or that locality; our place of residence, so far at least as a town or a district is concerned, is too often selected for us by circumstances over which we have little if any control, so that all that is left for us to do is simply to imitate, as far as possible in regard to our actual dwelling, those climatic conditions which have been found to be most favourable to immunity from rheumatic affections. These have been found to be, free exposure to the winds, especially such as are sea-winds, as by this free flushing the air-sewage, which may be both of animal and of vegetable origin, is not only driven off, but also to some extent probably neutralised by the chemical action of the ozone so largely contained in sea-air. We must, therefore, in our selection of a house, endeavour to procure an elevated, dry, gravelly site, freely exposed to the wind, or which, at all events, is so situate that it can be freely ventilated, and we must be careful to give those airs, fraught with blessing, free access to our living and sleeping apartments, and in doing so we must avoid the

two evils of chilling the rooms and producing draughts, both of which would certainly be injurious to the inhabitants, but both of which are quite easily avoided. These, however, are matters of detail; but it is well to remember that they are not only very important, but also perfectly attainable. While thus attending as far as possible to the removal of what has been aptly termed air-sewage, we must also see that the drains are perfect, and thoroughly disconnected with the house, so that all contamination from that cause is impossible; and we must also secure an abundant supply of pure and wholesome water, as perhaps as important an agent in the preservation of health as fresh air itself. Few people are aware how important an agent pure water is, but if we reflect that every act of life consists in the oxidation of the material of which our body is composed, that this oxidised material must be dissolved, floated off, and thrown out of the system in solution, while at the same time fresh unoxidised material must be floated into the body to replace what is thrown out, then we can understand the importance of an abundant supply of pure water, which removes the effete material from our blood, where it is even more likely to prove injurious than in our drains. We can also do a great deal to secure the purity of our blood from effete material by moderate living; for some individuals there seem to be certain

special articles of diet which apparently have an important effect in inducing or keeping up a tendency to rheumatism; animal food is one of these, especially if taken in excess, milk and fish having the least rheumatic tendency of all such nitrogenous or animal foods; sugar, too, is much blamed by some. It seems probable, however, that so far as rheumatism is concerned, it is mainly such articles of diet as are indigestible, or that are taken in excess, that are in themselves injurious. For we find rheumatic patients in all classes, and perhaps more often among those where actual excess is not very common, though dyspepsia is at least as frequent. Along with moderate living we must also have regular daily exercise, for "in the sweat of thy face shalt thou eat bread, till thou return unto the ground," and any infraction of this fiat is sooner or later injurious; the sweat glands get blocked, effete material accumulates in the blood, extra work is thus thrown upon those glands, such as the lungs and the kidneys, by which the system throws it off. The whole art of warding off rheumatism, then, consists in leading as natural a life as possible; living moderately in a freely ventilated, properly drained house, in an airy situation, exposed to as much sunlight as possible, and keeping all our organs in good working order by regular daily exercise.

Many simple inflammatory affections of the heart produce results very similar to those of rheumatism; so

far as we at present know, this is, however, but seldom the case, and when they do occur they must be regarded as simple accidents, and wholly unavoidable. It is true that there are some who look upon rheumatism also in this light, and regard it merely as an ordinary inflammation of the fibrous tissues, but there are many indisputable facts both in regard to the treatment and history of the disease which render this extremely improbable, and which tend to confirm the ordinary idea of its being the product of a poison of a distinctive character.

Hitherto, the forms of disease referred to have been such as are more or less strictly limited to youthful or early adult life, and in them the heart is that part of the circulating system primarily affected; but there is a very important series of diseases which are strictly senile in character, affecting the arteries primarily, and the heart only secondarily. These diseases are of the most variable character; they include the agonising and suffocative breast-pang, every form of valvular lesion of the heart, besides diseases of the kidney, liver, lungs, brain, and, indeed, of every organ of the body. Diseases which either originate directly in an abnormal condition of the arteries, or indirectly through the secondary disturbance of the heart's function, or which have their fatal tendency impressed on them by that imperfection of the heart's function, all these diseases are of a senile character, but

those attacked by them are not necessarily old, nor are all old people of necessity affected by them; quite the contrary; some of the very oldest of mankind—even those who have overlived one hundred years—have been found, after death, to have had arteries as elastic as the youngest and healthiest amongst us, and their great age has been, with apparent truth, attributed to this cause. For it is a trite but true axiom that a man is never any younger than his arteries. Whatever his actual years may be, he is either to be reckoned young or old, according as his arteries are youthful and elastic, or aged and rigid; and from this point of view a man may die of extreme old age long before he has exhausted his normal span of seventy years. How important, then, it must be to ward off this senile condition of the arteries, and to maintain their youthful elasticity as long as possible, as, once this has been lost, there is no possible restoration; and all that remains is to put on the drag and thus secure that the descent to our last home is made as slowly and gradually as possible. Now and then when symptoms have been neglected, and the descent for a time has been unusually rapid, the putting on of the drag by a firm and skilful hand has all the seeming effect of a cure, but it is both foolish and unmanly to be thus deceived, though in the prematurely aged it is perhaps excusable.

The affection of the arteries which gives rise to all

these changes, and which thus inaugurates our descent to the tomb, may be called by the comprehensive term arterio-sclerosis. This term means simply hardening of the arteries, and includes every change from the slightest loss of elasticity up to such a complete change of the arterial walls that they feel and look like branches of coral. The result of this loss of elasticity of the arterial walls is that there is a very much greater strain thrown upon the interior of the ventricle, that is, the left ventricle, for it is only the aortic system that is affected; the result of this is dilatation first and hypertrophy afterwards, in fact all the changes which are comprehensively included in the term gouty heart. At other times the inflammatory action to which the sclerosis is due invades the lining membrane of the heart, and attacking the valves may produce incompetency of these, and all the secondary results which flow from that. The causes of this premature or excessive arterio-sclerosis are partly such as have been bequeathed to us by our ancestors, and partly such as have been acquired by ourselves. Amongst the former, or those bequeathed, syphilis and gout are the most important, and of these syphilis ought perhaps to be considered the only one positively bequeathed, as in these circumstances it is strictly congenital, and its effects cannot be prevented from occurring by any care on our part; while, although

the tendency to gout is congenital, yet its manifestations may be largely, if not altogether, prevented by proper care. Amongst the causes of arterio-sclerosis which may be acquired we may reckon rheumatism, chronic alcoholism, syphilis, gout, lead poisoning, and injury.

Of rheumatism and its prevention enough has already been said, and we need not recur to it; it is the same disease whether it gives rise to an endarteritis or an endocarditis, and though affections of the arteries are not so common from this cause as affections of the heart, they have the same evil habit of occurring early in life.

Chronic Alcoholism is also a frequent cause of arterio-sclerosis, and this mainly in early adult life. It is believed to act by causing strain of the lining membrane of the arteries by stimulating both the arterioles and the heart to excessive action. This of course results in increase of the intra-arterial blood pressure, as the heart throws the blood with great force and rapidity into the arteries, while the arterioles let it escape more slowly, hence strain and injury to the elastic middle coat of the arteries, followed by chronic inflammation, ending in arterio-sclerosis. As we may readily suppose, the abuse of alcohol is more rapid and certain in its action when it is assisted by the co-existence of other causes, or by anything which of itself

helps to raise the blood pressure, especially when acting in this abnormal condition. Hence the abuse of alcoholic drinks, which is a menace to the health in various ways as well as in this, is especially dangerous in the very circumstances which are often pleaded as an excuse for this indulgence, viz., where there is need for continuous and violent exertion. We must also ever remember that occasional acts of drunkenness, however disgusting or degrading in themselves, are not nearly so dangerous to the health of mankind as that continual saturation of the system with alcohol, which is so often regarded as at least a venial offence, if not quite up to the highest standard of morality; and we must also remember that no accidental instance of a long life passed, with apparent impunity, in a constant breach of the law of temperance, is of any value as a proof that chronic alcoholism is not a dangerous condition, for it is of course in this, as in everything else, exceptions that prove the rule. The abuse of alcohol is next to syphilis, and perhaps, quite as often as that scourge of mankind, one of the commonest causes of heart disease from early senility of the arteries; it is a matter, however, which is entirely in our own hands, and he who knowingly persists in his vicious habits, after fair warning, is a suicide of the worst type. Would it be better for us all therefore to be teetotallers? is a question which may be

very pertinently asked; it is one, however, which is not so easily answered, because it seems very unlikely that alcohol should be so widespread, so easily obtained, and so constantly imbibed in one form or other by all classes and all races of men if it did not serve some good end in the economy of nature. Moreover, it would almost seem as if the depressing influences of our present civilisation, such as the overcrowding of our large cities, &c., gave rise to such a weakly habit of body in many as almost to necessitate the daily use of a certain amount of alcoholic fluid. For these, as well as for all, the Christian rule of "let your moderation be known of all men," seems to be a very much safer, as well as a much higher, standard of morality than any teetotal dogma.

Syphilis is a matter much more easily disposed of; probably it is the most common cause of by far the larger proportion of diseases which shorten life, arterio-sclerosis among them, but absolute prevention is the only cure. Once contracted, it pervades the system through all time, and affects generations yet unborn; much may be done for it by appropriate medical treatment, its outbreaks may be shortened and it may be kept in abeyance, but it is never cured, and it may break out at any moment. For congenital syphilis there is no perfect cure; it is believed to die out in the course of successive generations, it is to be hoped it may in some cases do so;

but as a rule it is the victims which die out and not the disease.

Gout belongs very much to the same category as rheumatism; it, too, is a sewage poison, but the accumulation of the effete and injurious material is not in the air around us, but within us, in our blood. It is a disease of civilisation, and appears to be largely, but probably not altogether, due to excess in food and drink above the wants of the body, and to deficient exercise. It is not, now-a-days at least, confined to the upper ten thousand, if it ever was so. Sydenham flattered himself that he suffered in common with kings, men of illustrious rank, and philosophers, and that his disease had killed more rich men than poor, more wise men than fools. This is but a poor consolation, especially when coupled with the fact that his sufferings were, as we now know, shared by coalheavers and the lowest scum of the earth. Perhaps there were no such people in his day; more probably he was only ignorant of their diseases. Moderate living and abundant exercise have long been known as the best preventives of gout; to live upon sixpence a day, and earn it, has been said to be the best cure; and there is no little truth in the statement. The late Dr. Gairdner, of London, in his interesting work on Gout, relates that Dr. Gregory, of Edinburgh, struck by the serious sufferings he had witnessed among his relatives, resolved, at

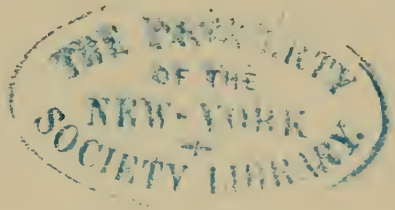
an early period of life, to subdue the tendency to the disease in himself. He prescribed to himself a frugal diet, with much bodily exercise, and by strict adherence to these rules he attained his object of being the first individual of his family who lived and died free from gout. In the same author we also find the following instance of a cure :—" A gentleman of the Stock Exchange suffered so much from gout as to become quite a cripple. He was seldom seen but wrapped in flannel at his chimney corner, where, notwithstanding, he retained great cheerfulness of character. He was overtaken by one of those great reverses of fortune to which persons in his profession are so much exposed. Compelled by necessity, and assisted by abstinence, he returned to business, and surprised his friends by becoming once more one of those hurried and nimble individuals so well known to all men who frequent the city." It would be vain to expect such cures to be frequent; the prevention of gout is more easily attainable, and in carrying out the necessary regimen it is important to remember that the skin, the kidneys, and the lungs are the natural emunctories of the body, from which the waste materials of our bodies escape; the bowels, which most people are so anxious about, being really of comparatively trifling importance, because their contents are mainly the refuse of our food, and contain but little of the waste products

resulting from those transformations of energy which manifest our vitality, and which in many ways act as poisons.

INJURY is a source of arterial disease, and through that of the heart, none of us can escape, should it come in our way; but the injury due to over-violent exertion we have entirely in our own hands, and every one is responsible to himself for any dereliction of duty in respect of exercise, in which excess may be more immediately, but is not less certainly, dangerous, than defect.

The CLOTHING and ACCOUTREMENTS of soldiers, especially in conjunction with the violent exertion to which they are so frequently exposed in forced marches, &c., have often been blamed as a fruitful source of heart disease in the army, and doubtless with good reason; yet there is no reasonable doubt that the prevalence of syphilis and chronic alcoholism has at least doubled the sad tale of preventable cardiac mischief. In civil life the clothing can rarely be blamed, but it is right to remember that whatever restrains the movements of the chest, or of the limbs, or impedes the free passage of the blood from one part of the body to another, must necessarily throw an extra strain upon the heart, which may result in disease, and must certainly largely augment the evil resulting from any other injurious influences which may coexist.

From what has been said, it is evident that mankind have a great deal in their own power in the way of preventing any disturbance of the heart's function, while the necessary measures are all of such a kind as must of necessity improve their health, increase their mental energy, and lengthen their lives.



THE END.

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